Integrated Landscape Analysis

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Executive Summary

The Bureau of Land Management manages 264 million acres of public lands. This presents unique challenges and opportunities for management of these lands, especially on tight budgets. The Integrated Landscape Analysis (ILA) process can provide BLM administrators with a tool for helping to manage these lands. The ILA methodology uses Geographic Information Systems technology to assemble and integrate digital data. Then experienced specialists put all this data and knowledge together to provide a complete analysis of landscapes. This report discusses some of the many ways that ILA can be used to support land management activities.

Methodology

ILA uses many different layers of geographic information, compiled and analyzed within the framework of a GIS. Some of the methods used include terrain analysis, which shows terrain patterns across a landscape. Cluster analysis is also used to display groupings of selected attributes for modeling potentially similar areas, such as ecological sites.

Applications

The ILA methodology has many different applications for BLM land managers. These include:

- Soil Survey
- Ecological Site Inventories
- Watershed Analysis
- Predictive Erosion Modeling with RUSLE
- Threatened and Endangered Species Habitat Modeling
- Monitoring Site Selection
- Riparian Area Identification and Management
- Archaeological and Cultural Site Prediction and Inventory
- Off Highway Vehicle Surveys

Experiences and Lessons Learned

The ILA appproach has been successfully demonstrated in the following areas:

- Sagers Wash, UT
- Henry Mountains, UT
- Empire Ranch, AZ
- Wamsutter and La Barge, WY
- Alamogordo, NM
- Emery County, UT
- Colorado NRI Rangeland Health

The ILA process has evolved from initially assisting manual soil survey approaches to using automation with new technology that allows for more and faster data analysis. This approach brings resource specialists and land managers together to share knowledge, experiences, skills and setting and resource data. Experience and knowledge combined can make ILA a successful solution for a variety of problems facing land managers today.

I. Introduction

A. Background

As the nation's population has grown, so have the demands on its public lands to provide multiple resources for a diverse clientele. Management of public lands has become increasingly complex, requiring sophisticated technologies and accurate information to serve a wide range of environmental, economic, and recreation needs (see Figure 1). The Bureau of Land Management (BLM) needs an efficient and economic process to compile and analyze a variety of multi-disciplinary resources over landscapes to determine the health and scientifically sound use of public land resources.

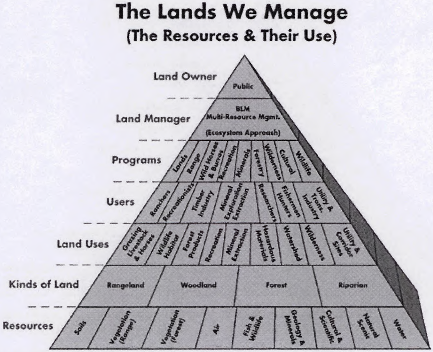


Figure 1. The Lands We Manage (reproduced from ILA handout materials).

Digital information is being collected to support and guide land management decisions. This data, which includes topography, geology, soils, vegetation, and climate data, as well as imagery, is being collected, organized, and analyzed using Geographic Information Systems (GIS) technology.

The Integrated Landscape Analysis (ILA) methodology uses this GIS technology to assemble and integrate Digital Elevation Model (DEM) data, Landsat Thematic Mapper (TM) imagery, orthophotos, digital coverage data, and tabular resource condition information. The ILA methodology, coupled with experienced specialists, puts all this data and knowledge together to provide a complete analysis of landscapes.

Landscape setting information is the same for all disciplines and is the key core data in many different fields of analysis. Unfortunately, few disciplines combine their data collection and

analysis efforts, resulting in redundant datasets and inefficient analyses. ILA combines the knowledge and specialized data collected by multiple disciplines to create a landscape analysis that is greater than the sum of its parts. Seeking this information conjointly in many fields for inventory and assessment can help avoid costly duplication of field efforts. Besides convenience and cost, the integrated approach provides a greater understanding of an area as a whole for planning and land management activities (see Figure 2). When a number of specialists are working together in the same area with a common objective, there are both opportunities and stimulus for the exchange of ideas and on-the-spot information which have scientific as well as practical value.

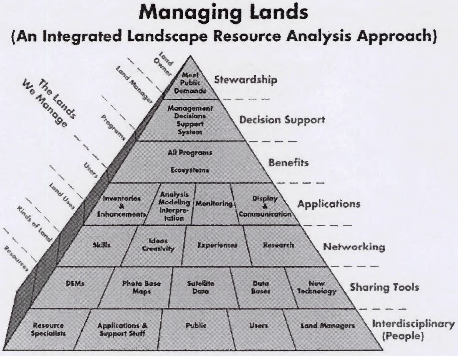


Figure 2. Managing Lands (reproduced from ILA handout materials).

The ILA methodology provides the opportunity to share tools and data and creates an environment for people (scientists, researchers, public, and decision makers) to network and share research information, knowledge, experiences, and creativity. Information and technology, using the ILA methodology, are also effectively used to display and communicate resource information, planning activities, land health, and its accompanying prescriptions to the public, bridging research with reality.

B. Past and Present of ILA

Before the current conception of ILA, the Soil Landscape Analysis Project (SLAP) began to use some of the same types of data used in ILA, but with manual overlays (black & white) produced from digital data. The SLAP methodology was developed by three federal agencies to enhance soil survey mapping procedures, improve the accuracy of soil survey, make soil scientists' field time more efficient, and assist in creating a digital soil database. The BLM and Natural Resource Conservation Service (NRCS) in cooperation with the U.S. Geological Survey (USGS) Earth Resources Observation Systems (EROS) Data Center jointly tested and evaluated the

application of SLAP methodology in making soil surveys and creating an accompanying digital soil database. (Amen, Foster, 1987 [1])

The SLAP methodology incorporated computer-generated slope, aspect, and spectral maps to assist soil scientists throughout the manual soil mapping process, resulting in an edited and verified digital data layer that is usable in a GIS database. The soil maps produced with the aid of these methods conformed to the standards and criteria of the National Cooperative Soil Survey (NCSS).

The ILA methodology has evolved from initially assisting these manual approaches, to using more automation with new technology that allows for more and faster data analysis. It currently provides improved quality, more economical surveys, and more effective display and enhancement opportunities for soil survey and landscape modeling.

The interpretation and analysis of multiple landscape attributes such as topography, vegetation, geology, and land use is an integral part of soil mapping. Traditional approaches that have been used to interpret landscape attributes when mapping soils involve air photo and topographic map interpretation coupled with field observations. Recent advances in GIS and allied technologies have created new opportunities for landscape interpretation using digital terrain analyses and multiple map overlay techniques. While these techniques will not necessarily provide new information, they do enable us to organize our existing information into a form that can expedite and improve soil mapping activities. The ILA approach includes techniques to combine statistically-based soil/landscape models with GIS data to create maps and information for resource modeling.

II. Methodology

A. GIS Data

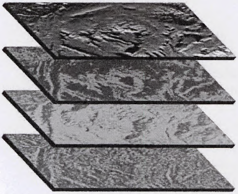
The goal of GIS technology is to model real-world features as geographic features, i.e. within a measurable framework. This includes all things located on or near the surface of the earth, including natural features such as rivers, soils, and vegetation, man-made constructions such as roads, pipelines or dams, and man-made subdivisions of land such as counties, states, and other political divisions. Just as paper maps and relief representations portray features on the ground, digital maps model the real world utilizing representative points, lines, areas, and surfaces (e.g. terrain surfaces), that describe those objects. The ILA methodology uses a 'toolbox' of these different GIS layers that are available to perform a variety of tasks (see Figure 3).

The ILA Toolbox

Aerial Photography – B&W, Natural color, Color IR and Orthophotographs

- Photographic Interpretation and Stereo
- Orthophoto Base Map – backdrop for recording soil polygons

Digital Elevation Models (DEMs)



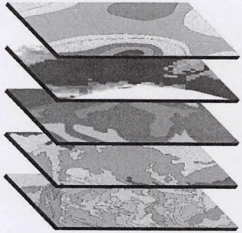
- Elevation
- Slope
- Aspect
- Curvature

♦ Landform Analysis
♦ Watershed Delineation
♦ Geomorphic Processes

Satellite Imagery - Landsat Thematic Mapper (TM)

- Soil Surface – Texture, OM, Color
- Geologic Substrate
- Soil Parent Materials
- Vegetation – Type, Biomass
- Rock Fragment Surfaces

Databases - Ancillary data



- Precipitation
- Temperature
- Geology
- Vegetation
- Existing Soils Data

♦ Public Land Survey System (PLSS)
♦Roads / Cultural features
♦ Land Use

Geographic Information Systems (GIS) Technology

- Computerized Integrated System – create, compile, store, model and display
- ArcInfo, ERDAS Imagine

Figure 3. The ILA Toolbox

The GIS toolbox used in ILA includes the following core landscape data and ancillary datasets:

- Orthophotography – aerial photo interpretations.
- DEM – elevation, slope class, aspect, curvature data, and climate landform data.
  - Elevation – delineates areas where elevation changes affect soil temperature, soil moisture, vegetation, and land use.
  - Slope – identifies degree of slope showing areas of erosion and landslide potential, and helping identify potential soil types along slope profiles.
  - Aspect – for mapping soils and vegetation in areas where aspect influences soil formation, soil temperature, and soil moisture, as well as vegetation type.
  - Curvature – displays hillslope curvature over the landscape, showing areas of erosion and deposition useful in determining soil types.
  - Climate landform – delineates broad soil groupings in landscape analyses.
- Landsat TM – for location of surface soil, geology, and vegetation.
- Precipitation – helps define soil polygons and ecological sites.
- Temperature – helps define soil polygons, ecological sites, and vegetation locations.
- Geology – helps define parent material when creating soil polygons.
- Soils – for creating new soil surveys in adjacent areas and refining existing large-scale soil surveys (e.g. STATSGO and SSURGO).
- Vegetation – for soils, wildlife, and rangeland management applications (e.g. GAP).
- Ancillary vectors – such as stream networks, Public Land Survey System (PLSS), roads, and land use data to help in management decision making.

Another important layer in the ILA toolbox is the band ratio composite. This imagery uses combinations of bands from a standard Landsat TM scene to display soil surface color and chemical composition information. Many soil characteristics have been shown to be significantly correlated to Landsat digital values, which have a strong covariance relationship with soil color. Experience has shown that the band ratio combination 3/2(R), 3/7(G), 5/7(B) is the best combination to use for relating surface features of arid landscapes to TM satellite data. Researchers have pointed out that the color of the earth's surface features on non-vegetated or sparsely-vegetated landscapes is very strongly correlated to energy reflected from these land surfaces, which is typical of our Public Lands.

In the past these tools have been used separately with mylar overlays, which is not as effective as using them in combination with automated analysis tools in the appropriate sequence. Traditionally, soil polygons have been interpreted for polygon placement and documented on aerial photography or orthophotos. A more in-depth analysis can be performed by supplementing the orthophoto backdrop with slope class, curvature, and TM reflectance data.

Although current policies facilitate sharing data throughout the BLM, there is no standard for posting the data in an accessible location. Thus, data is not shared, but is purchased and analyzed repeatedly. If this core data were made more available to resource specialists, analyses done would be more consistent, and could be used together for a greater understanding of management issues. Other data that the BLM already has access to includes Landsat TM scenes, GAP vegetation, STATSGO soils data, and other vector data at scales of 1:250,000 and greater. More detailed data, such as SSURGO soils data, may or may not be available in all areas.

Estimated costs of producing core data for the ILA 'toolbox' (including orthophotography, DEM data, and satellite Landsat TM data) and the accompanying key products derived from the core data averages from 1 to 2 cents per acre, including GIS technical assistance.

B. Methods & Models

An essential aspect of ecosystem management is the analysis of spatial and temporal relationships within a landscape between its various elements such as hydrologic response units, soil types, ecosites, landforms, watersheds, ecosystems, ecoregions, etc. Computer spatial data processing technology permits analysis of these landscape elements and their relationships, and assists in the development of sound management alternatives. ILA provides the means to integrate data and specialists from various disciplines and sources, to help management activities at various scales and resolutions.

Explicit models for spatial prediction provide a scientific approach to soil survey, but they do not utilize all of the predictive capacity of intuitive mental models used in conventional survey. For example, an experienced soil scientist usually draws on relationships between soil and environment variables gained in other landscapes when mapping a new area. The ILA approach integrates digital data (terrain and remote sensing), providing for a complete correlation landscape analysis representing each element of the ecosystem using each digital dataset most effectively.

Another facet of conventional practice difficult to incorporate into a more quantitative system is the large amount of continuous observation that goes into intuitive mental models. Quantitative models use data from observations at selected sites; however, many impressions of relationships between soil and other environmental variables are obtained as the survey area is traversed (e.g. opportunistic observations of road cuts, soil pits, sample sites, and other exposures).

1. Terrain Analysis

What GIS can offer can be exemplified by automated spatial terrain analysis tools that are available for evaluation and land modeling activities such as hillslope analysis, watershed analysis, and drainage pattern analysis.

The advent of digital terrain analysis and allied technologies has created an opportunity to develop a more scientifically-based method of soil survey that overcomes several of the limitations of conventional survey. Terrain analysis is of value to soil survey and land evaluation, even in landscapes where soil/landform relationships are weak or complex, because it can be used to generate useful environmental information and provide a basis for visualization. Terrain analysis can be utilized in ILA in three main areas:

1. To generate high-resolution information for use in land evaluation (slope, surface curvature, watershed delineation, aspect, elevation lines, water flow patterns, and topographic data).
2. To create explicit environmental stratifications for soil survey design.
3. To provide quantitative spatial predictions of individual soil properties.

A slope map generated from DEM data is one of the most effective products in mapping soils and ecological sites. Since topography is one of the most important factors in soil formation, use and management, slope-class maps generated from DEM data provide a good physiographic base for identifying soil delineations. Slope-class maps can also be used effectively in conjunction with aerial photographic interpretation (stereoscopy) to identify slope gradients.

The full potential of terrain analysis in soil survey will be realized only when it is integrated with field programs with a strong emphasis on geomorphic and pedologic processes. The use of quantitative terrain variables as predictors of soil distribution is in its infancy and evidence of its worth along with methodological refinements will have to be accumulated in a broad range of landscapes. Subjective terrain analysis has been central to soil survey since its inception.

2. Cluster Analysis

Cluster analysis is a general term for a family of statistical classification methods that group objects. The idea is to minimize variability within a group while maximizing variability among multiple groups in order to produce relatively homogeneous groups that are distinct from one another.

The more familiar hierarchical collective clustering methods develop a similarity matrix (e.g. a correlation matrix) for all cases, which allows a soil scientist to create a dendrogram that shows the relationships among all cases (i.e. pedons). The resulting dendrogram can be viewed as an indicator of distance measures from the central concept in multivariate space.

The soil groups defined by cluster analysis are pedologically similar and generally comprise mappable soil bodies. The effects of stratigraphy and landform on soil formation are evident in clustering results. The predictive value of landforms will vary between areas, but is very indicative of soil locations in wildlands areas.

Cluster analysis by selected TM band ratio maps, slope class, and surface curvature maps can reveal important pedological relationships that are not apparent when pedons are classified by landform aerial photographic interpretation alone.

III. Applications

The ILA methodology provides tools for soil inventory pre-mapping and enhancement, ecological site correlation, monitoring site selection, land capability determinations, risk assessment, and watershed modeling. The "Qualitative Assessment Procedure" (Pellant, Shaver, Pyke, and Herrick, 2000 [2]) for rangeland health is linked to the landscape by the ILA process. Indicators used in the assessment procedure (physical, chemical, and biotic environments) are given spatial definition, allowing key land health indicators and stressors unique to specific landscape settings to be more easily identified.

A. Soil survey

The ILA approach to making and enhancing soil surveys uses GIS technology to integrate DEM data, orthophotos, Landsat TM imagery, and other supporting data (climate, geology, vegetation cover, and adjoining soil data) for improved definition of taxonomic soil components within soil

mapping units. This methodology emphasizes a landscape and geologic analysis approach using a computerized overlay process in ERDAS IMAGINE, ArcInfo, ArcView, and other software analysis and display systems. The use of GIS landform/hydrologic characterization methods and additional geologic interpretations provide detailed information on the spatial variability of soil properties within soil map units.

The ILA process provides far more effective use of digital data for soil and ecological inventories and land health evaluations than have been used in soil surveys in the past. Through a GIS integration (data fusion) process, digital tools are used in combinations to most effectively depict spatial characteristics and landscape processes, bridging technology with reality in a sequential process.

The ILA methodology is especially effective when formulating pre-maps in areas where access is difficult or limited. ILA makes it easy to identify more representative areas to sample, thus reducing the time spent in the field. Direct sampling or digging of soil pits is an expensive and time-consuming process. Pre-mapping can help cut the cost of soil surveys by selecting more representative sample sites using existing environmental data.

ILA can also be used to supplement and update existing soil surveys. Supplemental mapping may involve subdivisions of larger map units using slope, curvature, band ratio composites, and other datasets. The ILA methodology emphasizes soil formation processes and provides a soil mapping model that relates soils and ecological sites to the landscape. The degree of correlation between soils and vegetation type to landscape and geomorphic processes allows inferences and prediction of soils and ecological sites. This assists in designing soil map units and ecological sites to be compatible with the landscape and to meet major user needs. Related resource data are also incorporated into the process of generating the inventory, which is helpful in describing the occurrence and extent of soil components and inclusions within a soil map unit.

The ILA methodology provides a good quality control and training tool for soil surveys and ecological site correlation. Inexperienced scientists can easily and effectively grasp concepts of soil mapping and ecological site correlation by using the ILA methodology because of the way that the environment is broken down into its simpler components.

The ILA approach to soil survey enhancement and ecological site correlation process provides additional interpretation and analysis capabilities for land management, e.g., watershed analysis, riparian area and grazing management, monitoring site selection and land health assessment. It also more effectively displays and communicates soil information and accompanying ecological site information, which are essential in managing public lands. One of the key references to help land use determinations and land health assessments is quality soil survey information that can be conveniently and effectively displayed and communicated.

The ILA approach allows any scale analysis (specific on-site to regional), with emphasis on 1:24,000 scale activities. The use of DEM and TM data alone cannot produce a soil survey. Field observations and soil sampling are still an integral part of the soil mapping process. However, with the ILA 'toolbox' and associated methodology, in conjunction with effective use of supportive data by experienced soil scientists, ILA can aid in making and updating soil surveys. Just as aerial photographs reduce field time and improve the accuracy of soil surveys,

the use of computerized technology has also become a valuable tool for soil scientists, other specialists, and resource managers in making and using soil surveys.

Experiences gained from pilot projects and activities conducted in Arizona, Nevada, Utah, New Mexico, and Wyoming indicate this approach to be very effective in wildlands and rangeland areas that have large areas of shallow and medium depth soils and accompanying exposures of geologic formations. Currently, this technology is being used in Emery County, Utah, soil survey, in cooperation with the National Resource Conservation Service (NRCS) to produce quality soil surveys more economically. All efforts identified are in accordance with NRCS guidelines.

B. Ecological Site Inventory, Range Health and Grazing Management

By permitting the overlaying of selected layers of geographically referenced information, the GIS facilitates the mapping of ecological sites, habitat types, plant community types, or any similar units of land classification, however defined by the user.

Experiences in the Colorado NRI pilot area were favorable when testing the process of ecological site delineation with the use of STATSGO soil data, indicating that soil data (plant growth medium) strongly influences the inventory process, which was to be expected. However, no follow-up testing was done using ILA with more detailed Order 3 soil survey (SSURGO) information which would have produced higher quality ecological site or range site inventories. This needs to be conducted in the future, especially in the Colorado NRI pilot area where field verification information, digitized core data, SSURGO soil survey, GAP vegetation data, and other necessary data is available. This area, which has an extensive GIS database, is excellent for evaluating and verifying different scales of existing soils data.

C. Watershed Analysis

The BLM is using GIS analytical techniques to assist with the development of comprehensive watershed management planning on rangeland and wildlands. The Sagers Wash watershed near Moab, Utah, was proposed as a prototype watershed for the reduction of salt input into the Colorado River. Soil erosion prediction (using the RUSLE/GIS interface), sediment yield, and salt input were modeled under various erosion control and grazing management practices to provide options for the best management alternatives. Data used include digital soil survey information, Digital Elevation Models, remotely sensed imagery, vegetation, surface geology, and resource condition information. GIS techniques were used for enhancing resource inventories and generating interpretations and analysis maps with accompanying records data to support resource management decisions.

The ILA methodology incorporates a strong landscape-resource analysis approach. Digital soil maps were interpreted for the parameters of precipitation, soil salinity, soil hydrologic groups, and presence or absence of various percentages and sizes of coarse fragments on the surface and other interpretations. Overlays were made for the various data themes and analyzed to produce a treatment opportunities map showing areas appropriate for various erosion control and grazing management practices, that could be utilized on the watershed.

The final step in the process involved selection of treatment priority areas for the watershed. The Public Lands Survey System (PLSS) theme was used to identify precise locations of streams and channels, proximity to pathways of sediment transport, and to locate archaeological sites, where erosion practices might impact the cultural resources. The methodology is also effectively used to display and communicate resource information and comprehensive planning activities. (Amen, Blaszczynski, Harte, and Page, No date [3]; U.S. BLM, Moab District Office, 1993 [4])

D. Predictive Erosion Modeling with RUSLE

An ecological issue of great importance is degradation of rangelands, the major symptom of which is an increase in the rate of soil erosion from wind and water. Technologies to estimate, manage, and contain soil erosion are very much needed to help prescribe management practices in order to maintain existing rangelands in an ecologically healthy state and to improve the health of degraded rangelands.

Since a significant portion of the public lands managed by the BLM are rangelands, the Bureau has a vested interest in issues related to rangeland soil erosion. Development and application of a soil erosion prediction methodology is therefore of utmost importance. The Revised Universal Soil Loss Equation (RUSLE)/Geographic Information System interface provides a methodology for regional level analysis of soil erosion, as well as for detailed analyses.

The RUSLE/GIS methodology permits calculation of potential soil loss from sheet and rill erosion for rangelands. The RUSLE equation calculates potential erosion (**A**) as follows:
$$\mathbf{A = R * K * L * S * C * P}$$
Where **A** is the computed soil loss per unit area, **R** is the rainfall and runoff factor, **K** is the soil erodibility factor, **L** is the slope-length factor, **S** is the slope-steepness factor, **C** is the cover and management factor; and **P** is the support control practice factor. In the modeling procedure the values for the different RUSLE factors are assigned to their respective mapping units, i.e. a soil unit map, a vegetation class map, and a digital elevation model for driving slope and slope length factors. (Amen, Blaszczynski, and Key, No date [5])

The erosion model/GIS interface can be used to model various possible management and ecological health scenarios by having the flexibility to change values of various environmental factors to simulate different conditions, such as moisture relationships, vegetation cover, and a variety of management practices.

Interfacing GIS analysis capabilities with RUSLE provides the resource specialist with a tool to quickly visualize likely sheet and rill soil erosion potential (soil detachment potential, but not transport and deposition) based on several major environmental parameters for large areas. This permits regional scale studies by quickly processing large amounts of information from data sources that are relatively easy to obtain from various government agencies.

Erosion models can serve as core methodology for further GIS hydrologic and geomorphologic applications such as analysis of watershed condition, sediment loading of streams and rivers, non-point source pollution, determining the effects of hazardous wastes in soils on water quality, etc.

E. Threatened and Endangered Species Prediction and Inventory

The ILA process provides the opportunity to model specific plant growth materials with selected setting factors to predict threatened and endangered species that require special soils in specific settings. This process allows prediction of the locations of these areas for protection and management.

F. Other Uses of ILA

- Monitoring Site Selection
- Riparian Area Identification and Management
- Archaeological and Cultural Site Prediction and Inventory
- OHV survey

IV. Experiences and Lessons Learned

The ILA approach initially started while providing assistance to field requests which benefited greatly from GIS applications. The experiences with the ILA approach used in field requests has proven to be a favorable and effective procedure for application of GIS in multi-resource planning, analysis, and land management implementation. The approach has evolved to include varying degrees of as experiences and knowledge were gained and GIS and allied technologies have advanced. Its development has been based on actual field request needs and activities providing a from-the-ground-up approach based on reality. Technology is only a tool. GIS by itself is not a solution, but rather a means to a solution. It only works when people know what to do with it.

The following examples are just a few of many field experiences using the ILA approach (see Figure 4):

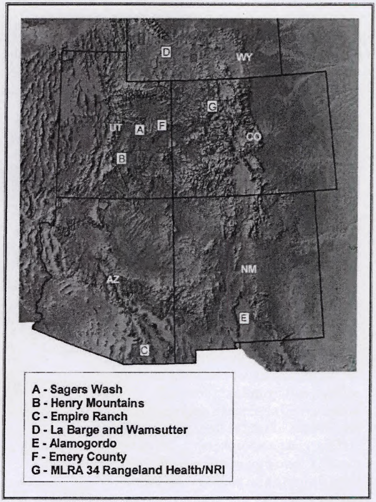


Figure 4. ILA Experience Locations

A. Sagers Wash Watershed, Moab, Utah

The effectiveness of ILA's GIS-based multi-disciplinary approach to watershed analysis and planning was successfully demonstrated during the development of the Greater Sagers Wash Comprehensive Plan. Development and production of interpretation and analytic maps was instrumental in visualization of the overall problem throughout the extent of the watershed, and in selection of appropriate treatment alternatives. Tabular summaries provided by the GIS were also useful. (Amen, Blaszczynski, Harte and Page, no date [6], U.S. BLM, Moab District Office, 1993 [4])

The Sagers Wash management plan was developed to:
1) Determine areas within the Sagers Wash Watershed with the highest potential for accelerated erosion, sedimentation, and salt production.
2) Determine areas with the highest potential for response to land treatments and/or resource management changes.
3) Develop alternatives for reducing sediment and salt production for these areas.
4) Determine which of the alternatives are economically feasible.

The Sagers Wash Watershed team was tasked to prepare a plan. After evaluating the size of the watershed, number of soil map units, ecological sites, and diversity of the area, it was decided that this would be an excellent opportunity for using GIS technology, which incorporates DEMs and TM scenes with the survey to provide quality base data, analysis, and modeling capabilities (see Figure 5).

GIS was used for the production of interpretation and analysis maps from digital soil data for the watershed. This process was also used in helping to determine and locate areas within the Sagers Wash watershed with highest potential for erosion, sedimentation, and salt production, highest potential response to land treatments and/or resource management changes, and in developing treatment alternatives.

Digital soil unit maps were interpreted for the parameters of precipitation, soil salinity, soil hydrologic groups, presence and absence of various percentages of coarse fragments on the surface, and geomorphology. Separate overlays were produced for each of these themes. The themes were then analyzed together to produce a Treatment Opportunities map, which shows appropriate areas for application of different erosion control practices

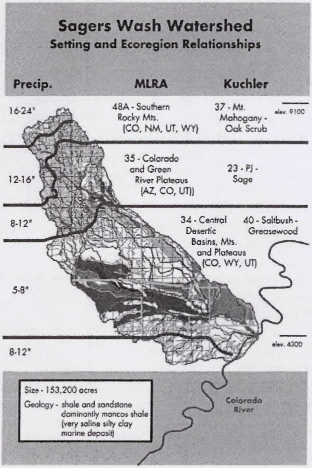


Figure 5. Sagers Wash Watershed

such as vegetation manipulation, pitting, contour furrowing, and development of detention, retention, and diversionary structures. Public Land Survey lines were also added to help identify precise locations, as well as streams and channels to help identify proximity to main pathways of sediment delivery. The suggested management techniques have been very effective in erosion control in the Sagers Wash area since the creation of the Greater Sagers Wash Watershed Management Plan in 1993.

B. Henry Mountains Soil Survey, Hanksville, Utah

The Henry Mountains project was a soil survey enhancement using modified Soil Landscape Application Project (SLAP) and ILA methodologies. Assistance in this area included application and demonstration of GIS technology and terrain analysis procedures (see Figure 6) to enhance an existing soil survey issued in February 1990. The goal was to improve interpreted values and identification of salt source areas within broad miscellaneous soil map units which make up more than one-fourth of the soil survey area. Six quads selected from the 1,200,000-acre soil survey were used to demonstrate the ILA methodology and its resultant products. This site was used as a prototype for enhancing Order 3 soil surveys in the West for the National Cooperative Soil Survey (NCSS) review, consideration, and acceptance. (Amen, Blaszczynski, Page, and Sheffy, no date [7])

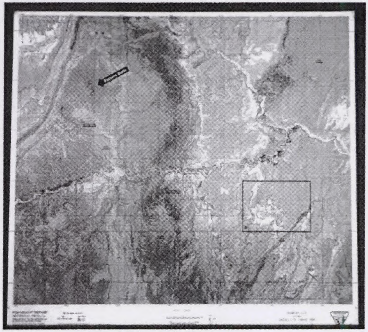


Figure 6. Henry Mountains Band Ratio Composite

C. Empire Ranch, Tuscon, Arizona

Empire Ranch was a field site for demonstrating GIS applications as related to Interdisciplinary Resource Training sessions conducted at the Phoenix Training Center.

Initially, two USGS quads were used for GIS applications, as well as GIS demonstrations, including enhancing soil surveys, RUSLE/GIS interface methodology and Soil Survey enhancement for riparian areas. This was also a WEPP test site for the profile, watershed and grid versions.

Later the GIS effort would be expanded to cover the entire ranch to provide for a ranch demonstration site (parts of five USGS quads).

D. Pilot Soil Survey Enhancement Areas, Wamsutter and La Barge, WY

The enhancement and correlation of existing scattered contractual soil surveys are common needs in several areas, especially in Wyoming. A four quad area in the Wamsutter area and a

four quad area in the La Barge area were tested with the ILA approach, using digitized DEM and TM products with the existing soil surveys. The experiences from these areas indicate that the ILA process is very effective and economical for enhancement and correlation on these rangeland landscapes and also provides additional ecological site inventory information.

Additional areas for soil survey in New Mexico, Nevada, and Oregon were also evaluated with the ILA approach.

E. Use of ILA for Predicting T&E Range Species (Inventory), Alamogordo, NM

Characterization of near-surface and soil micro-reliefs and physical/chemical and biological properties of surface soils is very important in predicting rare species. The genetic relationships are helpful in the development of prediction models for inventory of rare plant species. In order to use soil properties and related setting characteristics, the setting and soil property and related geology information was placed in an organizational framework using the ILA approaeh.

Areas with similar plant growth media (soils), landforms, and geologic materials can be identified and compared. The value of each habitat characteristic was determined at sites with and without cacti. Slope, aspect and soil type were assessed from digital and paper map data products for the field sites. Digital reflectance was assessed at the locations represented with TM imagery data.

F. Emery County Utah Soil Survey Pilot

With the experiences gained from the Henry Mountains Soil Survey, the Utah State Office proposed using the ILA process for conducting surveys in the Emery County Soil Survey. This survey area has similar landscapes, geology, geomorphic processes, and soils to the Henry Mountains Survey area. The intent was to:

1. increase the quality of the Soil Survey
2. include geologic interpretations
3. provide for selection of key areas for ground truthing
4. extrapolate field information in a very rough, inaccessible landscape
5. provide for more economical soil surveys
6. utilize the experiences and knowledge of an experienced resident soil scientist
7. provide for an accompanying ILA 'toolbox' for displaying soil survey information, associated environmental modeling (e.g. soil erosion modeling), ecological site inventories, risk assessment, and more detailed soil survey and site investigations.

The Emery County Utah Soil Survey study area consisted of three areas:

1) The "Green River" 12 quad area
2) The adjoining "Blocks" 6 quad area
3) The Western Emery 6 quad area

These areas are located along and north of the interstate highway 70 corridor. The soil survey activity consisted of a partially automated procedure using half-tone orthophotography as the backdrop on which to record soil polygons and for aerial photographic interpretations. The orthophotographs were supplemented by slope class maps and significant designated elevation lines, which were produced from DEMs. Curvature map interpretations were also initiated.

Aspect map interpretations were used where significant. Landsat TM band ratio maps were then used to supplement the soil polygon placement and to assist the description of the soil map unit (see Figure 7). The digital DEM and TM products were used as overlay maps. With the new technology capabilities, the overlay process can be more automated to provide for soil polygon placement with component percentages and inclusion units quantified.

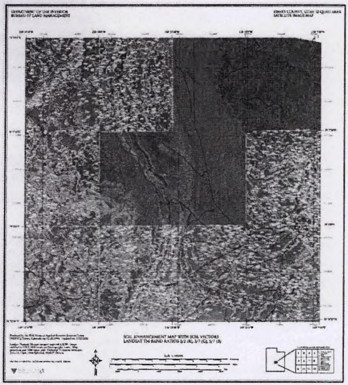


Figure 7. "Green River" Band Ratio with Soil Polygons

Experiences from soil survey activities conducted in this area even on a small year-to-year incremental basis (due to a lack of substantial funding) over a period of 3 to 4 years proved very favorable. Survey activities were conducted on 8 quads in the "Green River" area, 2 quads in the "Blocks" area, and parts of 2 quads in the "West Emery" area. The ILA approach allows a qualified, experienced soil scientist (preferably familiar with the area to be mapped) to conduct soil survey mapping activities in arid, wildland settings, where soils vary widely. A soil survey can be conducted more accurately, with higher quality, and at accelerated acreage rates with an accompanying ILA 'toolbox', which contains additional detailed information that can also be used to conduct revisions on inventories and ecosystem modeling.

Cost information including soil scientist's time, GIS products, travel, etc. were kept and analyzed, indicating the ILA approach to be very economical, in that it allows for more effective use of the soil scientist's skills, knowledge of the area and time. Soil surveys in Emery County, Utah, were produced at the rate of 35 to 50 percent of the ongoing dollar-per-acre rate, resulting in a savings of over $130,000 for an 8 quad tract (286,000 acres). Contracted costs for GIS product maps and accompanying assistance over a 4 to 5 year period was about $24,700. Cost-per-acre rates are available (Alan Amen, BLM).

The Emery County Soil Survey was an excellent opportunity to prove the validity of continuing the development of the ILA approach for conducting soil surveys in areas of native vegetation, areas that are strongly influenced by underlying geology, and areas that are very inaccessible. A key factor is the knowledgeable and experienced resident soil scientist who can effectively and accurately recognize, interpret, identify, and extrapolate the data from selected sample verification sites.

G. Colorado NRI Rangeland Health Pilot Area

The BLM National Resource Inventory (NRI) pilot project was conducted in Colorado in 1997. The effort was coordinated with the Natural Resources Conservation Service (NRCS) at the National and State level. 225 Primary Sampling Units (PSUs) containing two points each (total of 450 points) were inventoried and sampled to test and measure status and resource trends over broad areas. The 1997 Project area was located in Northwestern Colorado covering nearly 8 million acres. Vegetation production, ground cover, soil verification, and soil quality data were collected. A qualitative health assessment consisting of ecological attributes was also tested. The data collected reflects the condition of soil, water, and biotic plant communities.

In 1999, the Evaluating Remote Sensing and Data Management Technologies for use in Rangeland Health Assessments project consisting of a total of 22 sites (see Figure 8) was conducted to test various remotely-sensed spatial data processing methodologies and techniques. These sites are located entirely in western Colorado and are coincident with National Resource Inventory (NRI) sites identified by the NRCS in 1997. The sites chosen represent the dominant rangeland types occurring in Major Land Resource Area (MLRA) 34, consisting mainly of sagebrush, saltbrush, and juniper.

The NRI point data represents a 150-foot diameter area around each of 2 points within a 160-acre PSU (see Figure 9). This data provides the opportunity to evaluate the field point data with the ILA 'toolbox' approach to extrapolate this point data to the PSU, and from the PSU sample site (containing soils and ecological site inventory information) to larger landscape analysis.

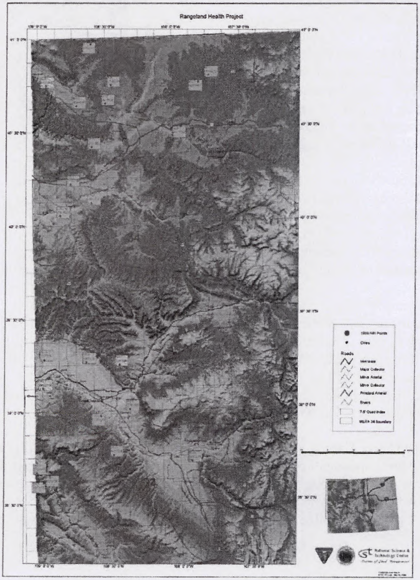


Figure 8. Rangeland Health Project Area

The NRI project experience provides an excellent opportunity to compare actual field observation data (including setting, soils, ecological site, and land health information) with digital core data (orthophotography, DEMs, and TM products) and the ILA approach (Habich, N., 1997 [8]). The NRI data collection sheets for site settings, soils, ecological sites (range sites), and qualitative rangeland health contain the field information needed to test and verify the ILA approach. Several representative NRI sites have been reviewed and found to be valid for this testing.

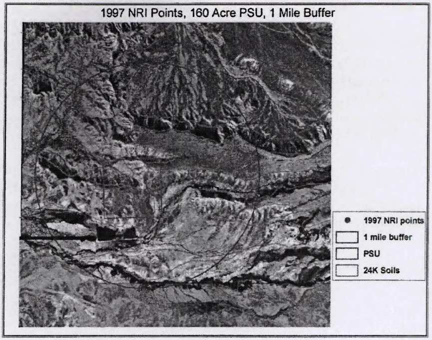


Figure 9. NRI Points, PSU, 1 Mile Buffer, and 1:24,000 Soils

Experiences in the Colorado NRI pilot area were favorable when testing the process of ecological site delineation with the use of STATSGO soil data. It indicated that soil data (plant growth medium) strongly influenced the inventory process, which was expected. However, no follow-up testing was done using ILA with the more detailed Order 3 soil survey (SSURGO) information which would have produced higher quality ecological site (range site) inventories. This needs to be conducted in the future, especially in the Colorado NRI pilot area where field verification information, digitized core data, SSURGO soil survey, GAP vegetation data, and other necessary data is available. The NRI area field data provides the opportunity to compare and correlate landscape setting data and accompanying soils and rangeland information gathered by the NRI crews with the ILA approach.

V. Conclusion

The ILA process has evolved from initially assisting manual soil survey approaches to using automation with new technology, which allows for more and faster data analysis. It is adaptable to all landscape analyses using a 'toolbox' of core digital data, providing a common environmental setting data package that can be shared by all programs. In addition to traditional soil survey polygon maps, the data collected through the ILA process can be used to conduct and enhance resource inventories, to provide for interpretations, landscape modeling, monitoring, and to effectively display and communicate spatial resource information. This approach brings resource specialists and land managers together to share knowledge, experiences, skills and setting and resource data. It also fosters the opportunity to put this information in the institutional memory, avoiding activities that constantly 'reinvent the wheel'.

The ILA approach, even though not completely automated, is operational with the key digital core data (orthophotos, DEMs, and TM) that is effectively utilized by experienced and knowledgeable resource and GIS specialists to conduct high quality resource inventories more economically, particularly on wildlands and rangelands in the West. There will be continued development and refinements made to the approach to incorporate additional GIS technology, knowledge, and experiences in surveys in the future, including the California Desert Soil Survey and recorrelation of existing contractual surveys. GIS is not a solution, but is a means to a solution to be used as a tool to assist resource specialists and land managers.

The strength of the ILA approach is the honest loyal team play between GIS applications and resource specialists, sharing tools, data, knowledge, and using their best skills. Remember, GIS technology is only a tool. Experience and knowledge combined can make it a successful solution for a variety of problems.

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